

**P8.4 SIMULATING THE BIDIRECTIONAL AND HEMISPHERICAL REFLECTANCE  
OF MOUNTAINOUS AND FORESTED SCENES WITH A GEOMETRIC-OPTICAL MODEL**

Crystal Barker Schaaf

and

Alan H. Strahler

Geophysics Directorate, Phillips Laboratory  
Hanscom Air Force Base, Massachusetts

Center for Remote Sensing, Boston University  
Boston, Massachusetts

**1. INTRODUCTION**

The intrinsic anisotropic properties of a forested surface are described by its Bidirectional Reflectance Distribution Function (BRDF). Therefore canopy shape and roughness parameters can be inferred from the BRDF of a scene or pixel. Furthermore, a bihemispherical integration of the BRDF generates a surface albedo or hemispherical reflectance for that pixel (an important quantity for energy budget and climate studies). With the advent of EOS sensors such as MISR (with its multiple views) or MODIS (with its wide across-track field of view), remotely sensed directional reflectances will be available to serve as samples across the BRDF of a surface. Physical models can be used in conjunction with this directional data to reconstruct the BRDF and ultimately retrieve surface characteristics or compute surface albedo values.

The Li-Strahler (1992) geometric-optical model has been used successfully to determine the BRDF and surface albedo of forested scenes. The model treats a canopied surface as an assemblage of partially illuminated tree crowns of ellipsoidal shape, and through geometric-optics and Boolean set theory, models the proportion of sunlit or shadowed canopy and background as a function of view angle. The model has been modified to accommodate a sloping surface in its computation of bidirectional and hemispherical reflectance. The model domain (or sensor FOV) is assumed to be smaller than the slope as the geometric-optical model produces direct beam results and does not accommodate the effects of diffuse radiation reflecting off of adjoining terrain.

**2. PROCEDURE**

To explore the variability due to topography, model bidirectional and hemispherical reflectances were calculated for a scene that realistically simulates an orographically complex region of the Sierra Nevada. Extensive field data from this region (Woodcock *et al.*, 1994) were available to initialize the geometric-optical model for three forest types (hardwoods, mixed conifers, and pines). Figure 1a shows the distribution of landcover types over the area, while in Figure 1b each different landcover/slope/aspect facet in the region is identified. The geometric-optical spectral results were combined to produce full spectrum albedos for each forest type (Brest and Goward, 1987). They were first

computed with a level terrain assumption and then computed for each slope/aspect facet. Several different illumination conditions were used to capture the variation in scene surface albedo over time.

**3. RESULTS**

Although the spectral BRDF of a forest type can display a distinctly different shape depending on the slope and aspect (Figure 2), there is little variability exhibited by the full spectrum hemispherical reflectance (Figures 3 and 4). The variation due to aspect is negligible except on the steepest slopes (30° and higher -- less than 10% of this scene). The scene albedos assuming level terrain are displayed as an image in Figures 3a and 4a while the scene albedos assuming realistic terrain are displayed in Figures 3b and 4b. The minimal differences between Figures 3 and 4 (mainly a general increase in the magnitudes of all of the albedos) are due to different illumination conditions. Topographic shading (with its obvious impacts on surface albedo) is not a problem (<2% of the scene) at either of solar positions.

**4. CONCLUSIONS**

The shape of the BRDF exhibited by a canopy can vary significantly depending on the slope and aspect. This raises concerns for the accurate reconstruction of a BRDF from a few remotely sensed directional measurements. However, albedo seems to be a fairly conservative value (although a significant variation in albedo can still be expected on extremely steep slopes (>30°) or on those slopes experiencing topographic shading). The differences in hemispherical reflectance due to species signature and tree shape, height and density appear to be more important than those due to slope and aspect. These results suggest that surface albedo can be specified on resolutions conforming to the surface cover rather than the complexity of the terrain.

**5. REFERENCES**

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- Li, X., and Strahler, A.H., 1992: Geometric-optical bidirectional reflectance modeling of the discrete-crown vegetation canopy: Effect of crown shape and mutual shadowing, *IEEE Trans. Geosci. Remote Sensing*, 30:276-292.
- Woodcock, C. E., Li, X., Collins, J., and Y. Wu, 1994: Inversion of the Li-Strahler canopy reflectance model for mapping forest Structure I: Calibration and parameter estimation, *IEEE Trans. Geosci. Remote Sensing*, in press.

*Corresponding author address:* C. Schaaf, PL/GPAS, 29  
Randolph Rd, Hanscom AFB, MA 01731-3010.

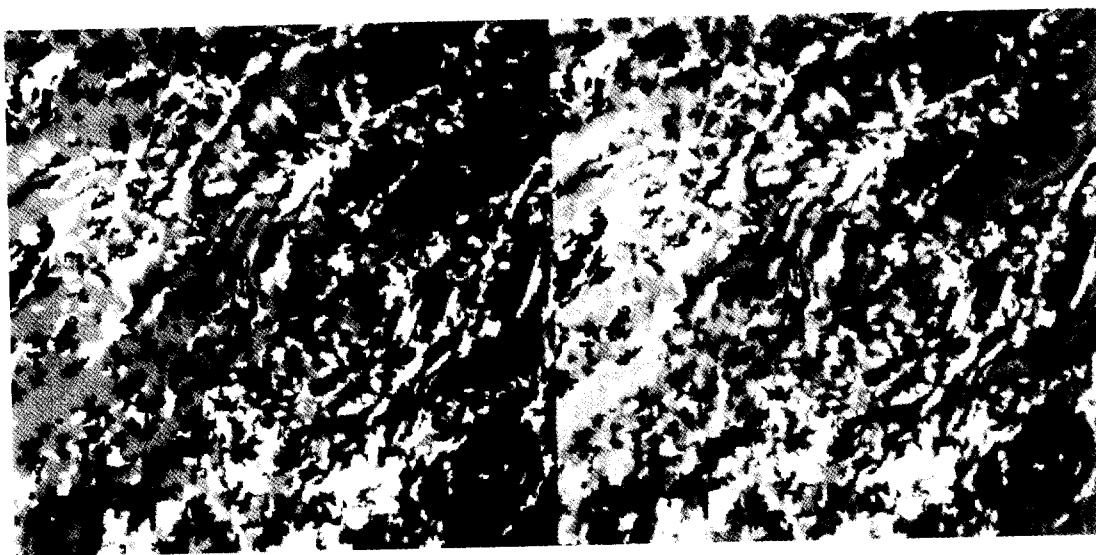


Figure 1. The distribution of landcover types (level terrain assumption) over the simulation scene (left) and the distribution of landcover/slope/aspect facets (right). The darkest shades are the hardwoods, the medium grey shades are the mixed conifers and the light grey shades are the pines, while nonmodeled landcovers such as water, barren, and brush are in white.

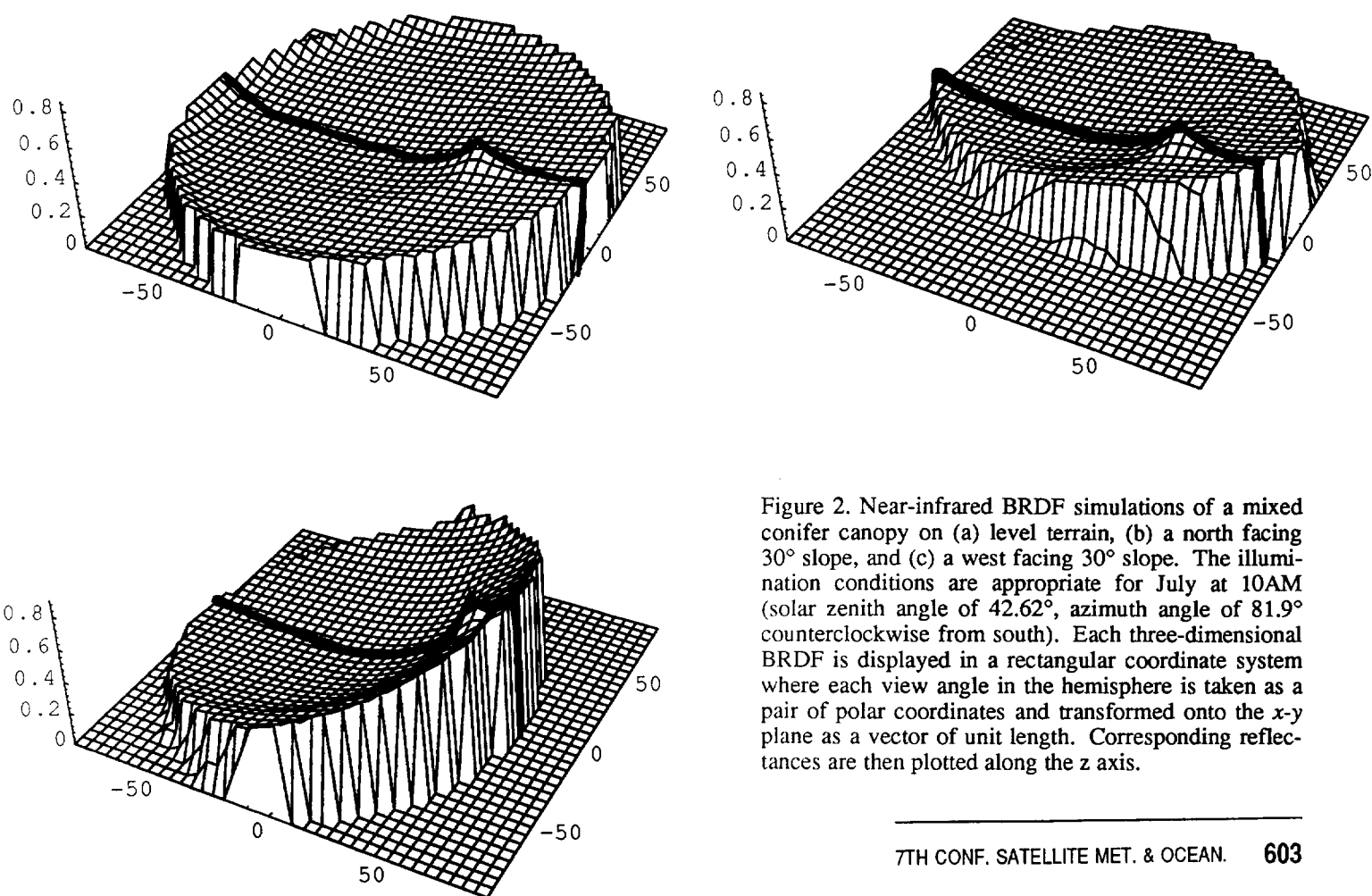


Figure 2. Near-infrared BRDF simulations of a mixed conifer canopy on (a) level terrain, (b) a north facing 30° slope, and (c) a west facing 30° slope. The illumination conditions are appropriate for July at 10AM (solar zenith angle of 42.62°, azimuth angle of 81.9° counterclockwise from south). Each three-dimensional BRDF is displayed in a rectangular coordinate system where each view angle in the hemisphere is taken as a pair of polar coordinates and transformed onto the  $x$ - $y$  plane as a vector of unit length. Corresponding reflectances are then plotted along the  $z$  axis.

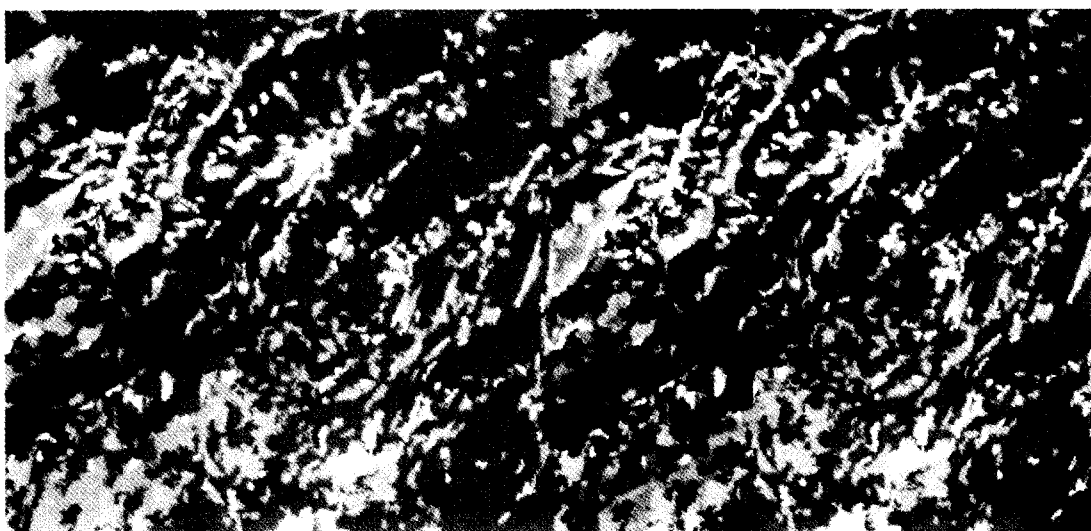


Figure 3. The morning (solar zenith angle of  $42.62^\circ$ ) albedos displayed as images. The modeled level terrain albedos for a morning solar zenith angle of  $42.62^\circ$  are .20 for hardwoods, .16 for mixed conifer and .14 for pines (left). The modeled topographic albedos range from .20 to .095 (right). The nonmodeled barren and brush is white and water is black.

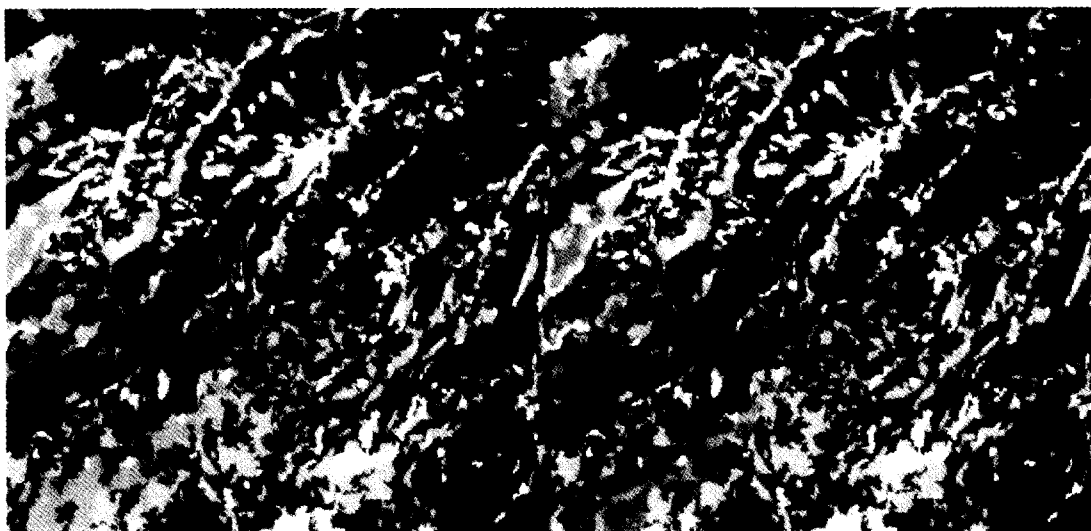


Figure 4. The midday (solar zenith angle of  $15.89^\circ$ ) albedos displayed as images. The modeled level terrain albedos for a morning solar zenith angle of  $42.62^\circ$  are .19 for hardwoods, .13 for mixed conifer and .12 for pines (left). The modeled topographic albedos range from .19 to .087 (right). The nonmodeled barren and brush is white and water is black.